Chapter 8. RTX-51 Real-Time Operating System

RTX51 is a multitasking real-time operating system for the 8051 family. RTX51 simplifies system and software design of complex and time-critical projects. RTX51 is a powerful tool to manage several jobs (tasks) on a single CPU. There are two distinct versions of **RTX51**:

RTX51 Full which performs both round-robin and preemptive task switching with 4 task priorities and can be operated with interrupt functions in parallel. RTX51 supports signal passing; message passing with a mailbox system and semaphores. The os_wait function of RTX51 can wait for the following events: interrupt; timeout; signal from task or interrupt; message from task or interrupt; semaphore.

RTX51 Tiny which is a subset of RTX51 Full. RTX51 Tiny easily runs on single-chip systems without off-chip memory. However, program using RTX51 Tiny can access off-chip memory. RTX51 Tiny allows round-robin task switching, supports signal passing and can be operated with interrupt functions in parallel. The os_wait function of RTX51 Tiny can wait for the following events: timeout; interval; signal from task or interrupt.

The rest of this section uses RTX-51 to refer to RTX-51 Full and RTX-51 Tiny. Differences between the two are stated where applicable.

Introduction

Many microcontroller applications require simultaneous execution of multiple jobs or tasks. For such applications, a real-time operating system (RTOS) allows flexible scheduling of system resources (CPU, memory, etc.) to several tasks. RTX-51 implements a powerful RTOS that is easy to use. RTX-51 works with all 8051 derivatives.

You write and compile RTX-51 programs using standard C constructs and compiling them with C51. Only a few deviations from standard C are required in order to specify the task ID and priority. RTX-51 programs also require that you include the **RTX51.H** or **RTX51TNY.H** header file. When you select in the µVision2 dialog Options for Target - Target the operating system, the linker adds the appropriate RTX-51 library file.

Single Task Program

A standard C program starts execution with the main function. In an embedded application, main is usually coded as an endless loop and can be thought of as a single task that is executed continuously. For example:

```
int counter;

void main (void) {
  counter = 0;

  while (1) {                                          /* repeat forever */
    counter++;                                       /* increment counter */
  }
}
```

Round-Robin Task Switching

RTX51 Tiny allows a quasi-parallel, simultaneous execution of several tasks. Each task is executed for a predefined timeout period. A timeout suspends the execution of a task and causes another task to be started. The following example uses this round-robin task switching technique.

Simple C Program using RTX51

```
#include <rtx51tny.h>                        /* Definitions for RTX51 Tiny */
int counter0;
int counter1;

job0 () _task_ 0  {

  os_create_task (1);                     /* Mark task 1 as "ready"       */

  while (1)  {                            /* Endless loop                 */
    counter0++;                           /* Increment counter 0          */
  }
}

job1 () _task_ 1  {
  while (1)  {                            /* Endless loop                 */
    counter1++;                           /* Increment counter 1          */
  }
}
```

RTX51 starts the program with task 0 (assigned to job0). The function os_create_task marks task 1 (assigned to job1) as ready for execution. These two functions are simple count loops. After the timeout period has been completed, RTX51 interrupts job0 and begins execution of job1. This function even reaches the timeout and the system continues with job0.

The os_wait Function

The os_wait function provides a more efficient way to allocate the available processor time to several tasks. os_wait interrupts the execution of the current task and waits for the specified event. During the time in which a task waits for an event, other tasks can be executed.

Wait for Timeout

RTX51 uses an 166/167 timer in order to generate cyclic interrupts (timer ticks). The simplest event argument for os_wait is a timeout, where the currently executing task is interrupted for the specified number of timer ticks. The following uses timeouts for the time delay.

Program with os_wait Function

```
#include <rtx166t.h>          /* Definitions for RTX166 Tiny */

int counter0;
int counter1;

job0 () _task_ 0  {

  os_create_task (1);

  while (1)  {
    counter0++;                /* Increment counter 0         */
    os_wait (K_TMO, 3, 0);     /* Wait 3 timer ticks          */
  }
}

job1 () _task_ 1  {
  while (1)  {
    counter1++;                /* Increment counter 1         */
    os_wait (K_TMO, 5, 0);     /* Wait 5 timer ticks          */
  }
}
```

This program is similar to the previous example with the exception that job0 is interrupted with os_wait after counter0 has been incremented. RTX166 waits three timer ticks until job0 is ready for execution again. During this time, job1 is executed. This function also calls os_wait with a timeout of 5 ticks. The result: counter0 is incremented every three ticks and counter1 is incremented every five timer ticks.

Wait for Signal

Another event for os_wait is a signal. Signals are used for task coordination: if a task waits with os_wait until another task issues a signal. If a signal was previously sent, the task is immediately continued.

Program with Wait for Signal.

```
#include <rtx166t.h>          /* Definitions for RTX166 Tiny */

int counter0;
int counter1;

job0 () _task_ 0  {

  os_create_task (1);

  while (1)  {
    if (++counter0 == 0) {     /* On counter 0 overflow       */
      os_send_signal (1);      /* Send signal to task 1       */
    }
  }
}

job1 () _task_ 1  {
  while (1)  {
    os_wait (K_SIG, 0, 0);     /* Wait for signal; no timeout */
    counter1++;                /* Increment counter 1         */
  }
}
```

In this example, task 1 waits for a signal from task 0 and therefore processes the overflow from counter0.

Preemptive Task Switching

The full version of RTX166 provides preemptive task switching. This feature is not included in RTX166 Tiny. It is explained here to provide a complete overview of multitasking concepts.

In the previous example, task 1 is not immediately started after a signal has arrived, but only after a timeout occurs for task 0. If task 1 is defined with a higher priority than task 0, by means of preemptive task switching, task 1 is started immediately after the signal has arrived. The priority is specified in the task definition (priority 0 is the default value).

RTX51 Technical Data

Description	RTX-51 Full	RTX-51 Tiny
Number of tasks	256; max. 19 tasks active	16
RAM requirements	40 .. 46 bytes DATA 20 .. 200 bytes IDATA (user stack) min. 650 bytes XDATA	7 bytes DATA 3 * <task count> IDATA
Code requirements	6KB .. 8KB	900 bytes
Hardware requirements	timer 0 or timer 1	timer 0
System clock	1000 .. 40000 cycles	1000 .. 65535 cycles
Interrupt latency	< 50 cycles	< 20 cycles
Context switch time	70 .. 100 cycles (fast task) 180 .. 700 cycles (standard task) depends on stack load	100 .. 700 cycles depends on stack load
Mailbox system	8 mailboxes with 8 integer entries each	not available
Memory pool system	up to 16 memory pools	not available
Semaphores	8 * 1 bit	not available

Overview of RTX51 Routines

The following table lists some of the RTX-51 functions along with a brief description and execution timing (for RTX-51 Full).

Function	Description	CPU Cycles
isr_recv_message †	Receive a message (call from interrupt).	71 (with message)
isr_send_message †	Send a message (call from interrupt).	53
isr_send_signal	Send a signal to a task (call from interrupt).	46
os_attach_interrupt †	Assign task to interrupt source.	119
os_clear_signal	Delete a previously sent signal.	57
os_create_task	Move a task to execution queue.	302
os_create_pool †	Define a memory pool.	644 (size 20 * 10 bytes)
os_delete_task	Remove a task from execution queue.	172
os_detach_interrupt †	Remove interrupt assignment.	96
os_disable_isr †	Disable 8051 hardware interrupts.	81
os_enable_isr †	Enable 8051 hardware interrupts.	80
os_free_block †	Return a block to a memory pool.	160
os_get_block †	Get a block from a memory pool.	148
os_send_message †	Send a message (call from task).	443 with task switch
os_send_signal	Send a signal to a task (call from tasks).	408 with task switch 316 with fast task switch 71 without task switch

Function	Description	CPU Cycles
os_send_token †	Set a semaphore (call from task).	343 with fast task switch 94 without task switch
os_set_slice †	Set the RTX-51 system clock time slice.	67
os_wait	Wait for an event.	68 for pending signal 160 for pending message

† These functions are available only in RTX-51 Full.

Additional debug and support functions in RTX-51 Full include the following:

Function	Description
oi_reset_int_mask	Disables interrupt sources external to RTX-51.
oi_set_int_mask	Enables interrupt sources external to RTX-51.
os_check_mailbox	Returns information about the state of a specific mailbox.
os_check_mailboxes	Returns information about the state of all mailboxes in the system.
os_check_pool	Returns information about the blocks in a memory pool.
os_check_semaphore	Returns information about the state of a specific semaphore.
os_check_semaphores	Returns information about the state of all semaphores in the system.
os_check_task	Returns information about a specific task.
os_check_tasks	Returns information about all tasks in the system.

CAN Functions

The CAN functions are available only with RTX-51 Full. CAN controllers supported include the Philips 82C200 and 80C592 and the Intel 82526. More CAN controllers are in preparation.

CAN Function	Description
can_bind_obj	Bind an object to a task; task is started when object is received.
can_def_obj	Define communication objects.
can_get_status	Get CAN controller status.
can_hw_init	Initialize CAN controller hardware.
can_read	Directly read an object's data.
can_receive	Receive all unbound objects.
can_request	Send a remote frame for the specified object.
can_send	Send an object over the CAN bus.
can_start	Start CAN communications.
can_stop	Stop CAN communications.
can_task_create	Create the CAN communication task.
can_unbind_obj	Disconnect the binding between a task and an object.
can_wait	Wait for reception of a bound object.
can_write	Write new data to an object without sending it.

TRAFFIC: RTX-51 Tiny Example Program

The TRAFFIC example is a pedestrian traffic light controller that shows the usage of multitasking RTX-51 Tiny Real-time operating system. During a user-defined time interval, the traffic light is operating. Outside this time interval, the yellow light flashes. If a pedestrian pushes the request button, the traffic light goes immediately into ***walk*** state. Otherwise, the traffic light works continuously.

Traffic Light Controller Commands

The serial commands that TRAFFIC supports are listed in the following table. These commands are composed of ASCII text characters. All commands must be terminated with a carriage return.

Command	Serial Text	Description
Display	`D`	Display clock, start, and ending times.
Time	`T` *`hh:mm:ss`*	Set the current time in 24-hour format.

Start	S *hh:mm:ss*	Set the starting time in 24-hour format. The traffic light controller operates normally between the start and end times. Outside these times, the yellow light flashes.
End	E *hh:mm:ss*	Set the ending time in 24-hour format.

Software

The TRAFFIC application is composed of three files that can be found in the **\KEIL\C51\EXAMPLES\TRAFFIC** folder.

TRAFFIC.C contains the traffic light controller program that is divided into the following tasks:

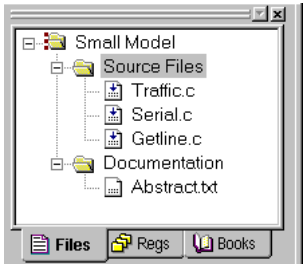
- **Task 0 init**: initializes the serial interface and starts all other tasks. Task 0 deletes itself since initialization is needed only once.
- **Task 1 command**: is the command processor for the traffic light controller. This task controls and processes serial commands received.
- **Task 2 clock**: controls the time clock.
- **Task 3 blinking**: flashes the yellow light when the clock time is outside the active time range.
- **Task 4 lights**: controls the traffic light phases while the clock time is in the active time range (between the start and end times).
- **Task 5 keyread**: reads the pedestrian push button and sends a signal to the task lights.
- **Task 6 get_escape**: If an ESC character is encountered in the serial stream the command task gets a signal to terminate the display command.

SERIAL.C implements an interrupt driven serial interface. This file contains the functions *putchar* and *getkey*. The high-level I/O functions *printf* and *getline* call these basic I/O routines. The traffic light application will also operate without using interrupt driven serial I/O. but will not perform as well.

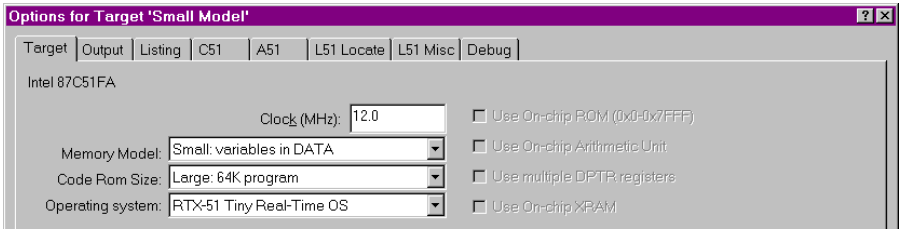
GETLINE.C is the command line editor for characters received from the serial port. This source file is also used by the MEASURE application.

TRAFFIC Project

Open the **TRAFFIC.UV2** project file that is located in **\KEIL\C51\EXAMPLES\TRAFFIC** folder with µVision2. The source files for the TRAFFIC project will be shown in the **Project Window – Files** page.



The RTX-51 Tiny Real-Time OS is selected under Options for Target.

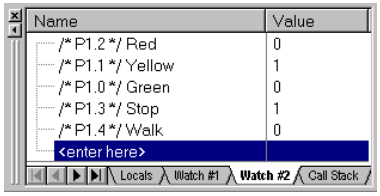


Build the TRAFFIC program with **Project - Build** or the toolbar button.

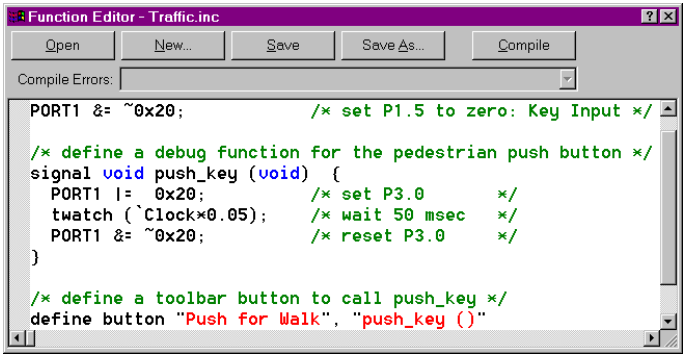
Run the TRAFFIC Program

You can test TRAFFIC with the µVision2 simulator.

The watch variables shown on the right allow you to view port status that drives the lights.



The **push_key** signal function simulates the pedestrian push key that switches the light system to *walk* state. This function is called with the **Push for Walk** toolbar button.



Use **Debug – Function Editor** to open **TRAFFIC.INC**. This file is specified under **Options for Target – Debug – Initialization File** and defines the signal function **push_key**, the port initialization and the toolbar button.

8

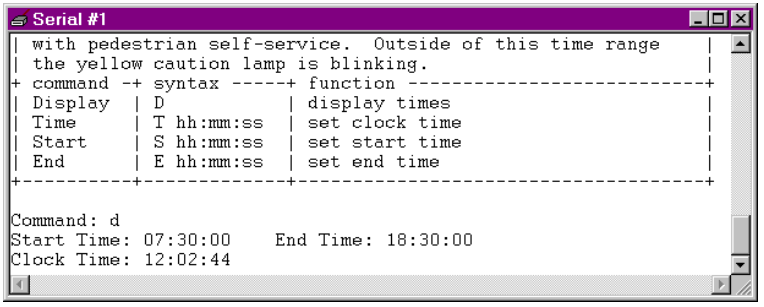
button.

Note: the VTREG symbol ***Clock*** is literalized with a back quote (`), since there is a C function named ***clock*** in the **TRAFFIC.C** module. Refer to "Literal Symbols" on page 109 for more information.

Now run the TRAFFIC application. Enable **View – Periodic Window Update** to view the lights in the watch window during program execution.

The **Serial Window #1** displays the *printf* output and allows you to enter the traffic light controller commands described in the table above.

Set the clock time outside of the start/end time interval to flash the yellow light.



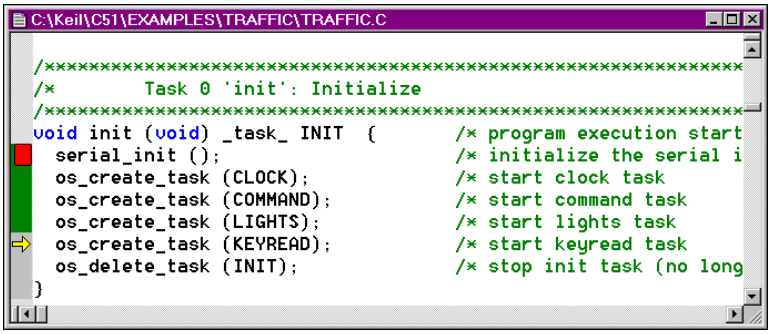
RTX Kernel Aware Debugging

A RTX application can be tested with the same methods and commands as standard 8051 applications. When you select an **Operating System** under **Options for Target – Target**, µVision2 enables additional debugging features: a dialog lists the operating system status and with the ***_TaskRunning_*** debug function you may stop program execution when a specific task is active.

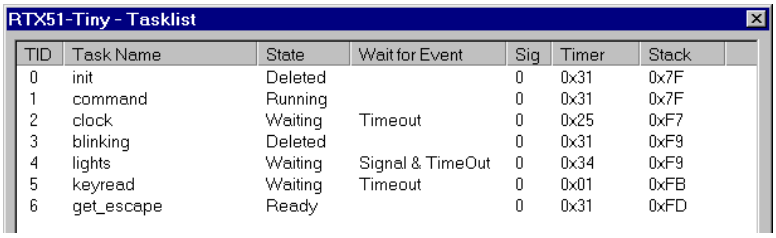
The following section exemplifies RTX debugging with the TRAFFIC example.

Stop program execution, reset the CPU and kill all breakpoints.

An RTX-51 application can be tested in the same way as standard applications. You may open source files, set break points and single step through the code. The TRAFFIC application starts with task 0 *init*.



µVision2 is completely kernel aware. You may display the task status with the menu command **Peripherals – RTX Tiny Tasklist**.



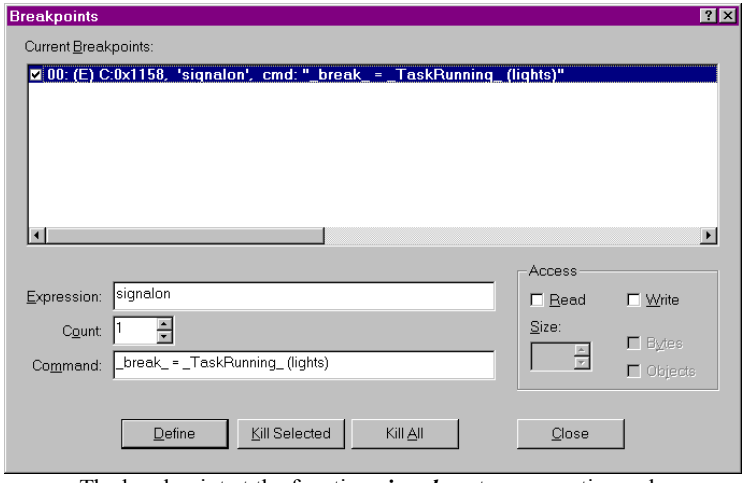
The dialog **RTX51 Tiny Tasklist** gives you the following information:

Heading	Description
TID	*task_id* used in the definition of the task function.
Task Name	name of the task function.
State	task state of the function; explained in detail in the next table.
Wait for Event	event the task is waiting for; the following events are possible (also in combination): **Timeout**: the task **Timer** is set to the duration is specified with the *os_wait* function call. After the **Timer** decrements to zero, the task goes into **Ready** state. **Interval**: the time interval specified with *os_wait* is added to the task **Timer** value. After the **Timer** decrements to zero, the task goes into **Ready** state. **Signal**: the *os_wait* function was called with **K_SIG** and the task waits for **Sig** = 1.
Sig	status of the **Signal** bit that is assigned to this task.
Timer	value of the **Timer** that is assigned to this task. The **Timer** value decrements with every RTX system timer tick. If the **Timer** becomes zero and the task is waiting for **Timeout** or **Interval** the task goes into **Ready** state.
Stack	value of the stack pointer (SP) that is used when this task is **Running**.

RTX-51 Tiny contains an efficient stack management that is explained in the "*RTX51 Tiny*" User's Guide, Chapter 5: RTX51 Tiny, Stack Management.
This manual provides detailed information about the **Stack** value.

State	Task State of a RTX166 Task Function
Deleted	Tasks that are not started are in the **Deleted** state.
Ready	Tasks that are waiting for execution are in the **Ready** state. After the currently **Running** task has finished processing, RTX starts the next task that is in the **Ready** state.
Running	The task currently being executed is in the **Running** state. Only one task is in the **Running** state at a time.
Timeout	Tasks that were interrupted by a round-robin timeout are in the **Timeout** state. This state is equivalent to **Ready**; however, a round-robin task switch is marked due to internal operating procedures.
Waiting	Tasks that are waiting for an event are in the **Waiting** state. If the event occurs which the task is waiting for, this task then enters the **Ready** state.

The **Debug – Breakpoints…** dialog allows you to define breakpoints that stop the program execution only when the task specified in the ***_TaskRunning_*** debug function argument is **Running**. Refer to "Predefined Functions" on page 122 for a detailed description of the ***_TaskRunning_*** debug function.



The breakpoint at the function ***signalon*** stops execution only if ***lights*** is the current **Running** task.